The JACEE Measurement of the Cosmic Ray Proton and Helium Spectra

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The Japanese-American cooperative emulsion experiment (JACEE) collaboration has now flown 15 balloon-borne experiments to measure the cosmic ray composition, energy spectra, and nuclear interactions above 10^{12} electron volts (1 TeV). Some of these flight opportunities included long-duration balloon flights from Australia to South America and circumpolar flights in Antarctica. The JACEE collaboration includes MSFC, University of Alabama in Huntsville (UAH), University of Washington (UW), Seattle, Louisiana State University (LSU), Institute for Nuclear Physics, Krakow, Poland, and nine universities located in Japan. The instrument package contains multiple layers of doubled-sided nuclear emulsion plates, CR39 etchable track detectors, x-ray films, and lead plates. The emulsion chamber is typically divided into a charge detector, a target section for interactions, a stack of honeycomb spacers, and an ionization calorimeter section for the determination of the cosmic ray energy. To achieve adequate exposure to the meager flux of high-energy cosmic ray protons and helium nuclei, six emulsion chambers , 1.2-m^2 and 20-cm thick, were flown at an altitude of 120 to 125,000 ft for 9 to 15 days. After repeated long duration balloon flights, a total accumulated exposure of 1,436 m^2 hr was realized. To date, we have analyzed 45 percent of this accumulated data resulting in 656 protons above 6 TeV and 414 helium nuclei above an energy of 2 TeV/nucleon. We present in figure 165 the JACEE differential energy spectra for both hydrogen and helium (filled circles) together with previous measurements for comparison. The kinetic energy scale is expressed in units of GeV/nucleon where GeV = 10^9 electron volts. Both the JACEE proton and helium data can be fit with an inverse power law in energy with spectral indices $\gamma_H = 2.69 + 0.13/-0.05$ and $\gamma_{He} = 2.54 + 0.13/-0.04$, respectively. We can conclude from this inverse power law fit that the H/He ratio gradually decreases with increasing energy. A helium spectrum slightly flatter than the hydrogen spectrum

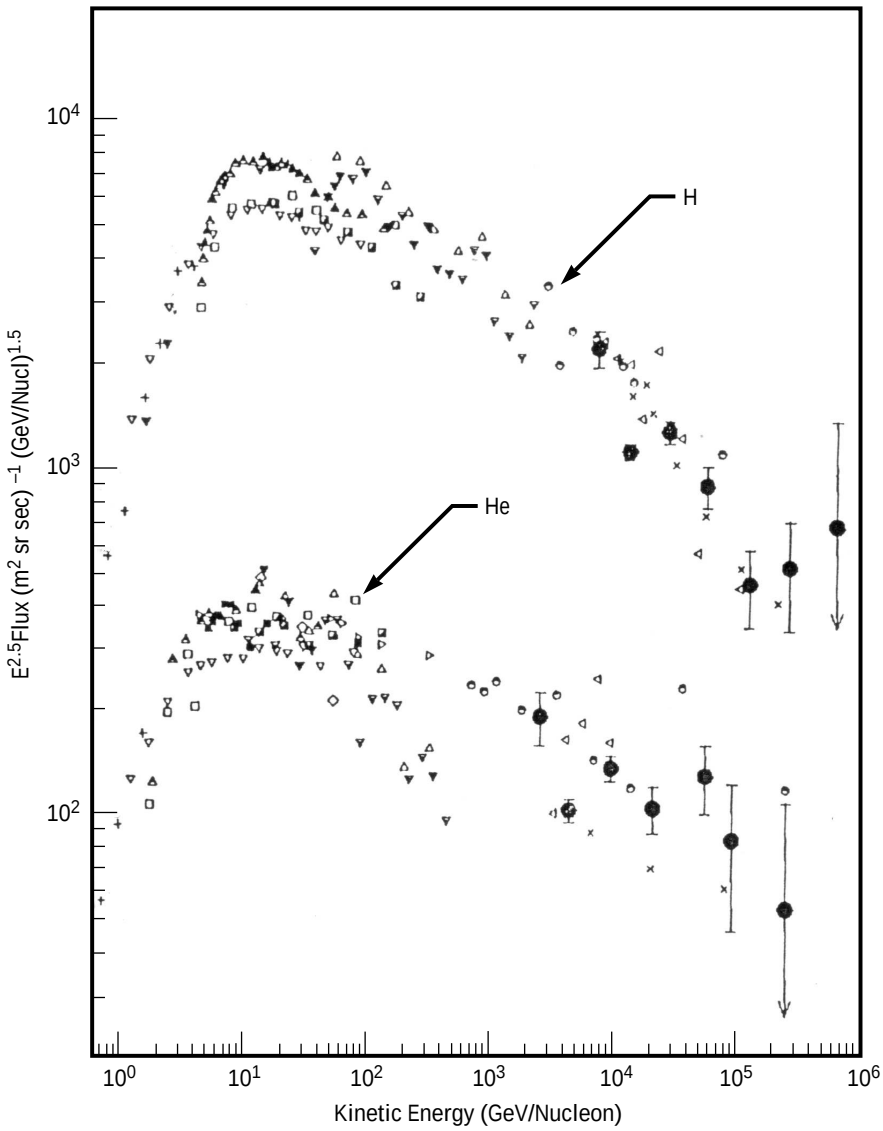

FIGURE 165.—The differential energy spectra of cosmic ray hydrogen (H) and helium (He) showing the latest JACEE results (●) together with earlier results from Frier and Waddington (1968, +), Anand et al. (1968, ■), Ryan et al. (1972, Δ), Verma et al. (1972, ◇), Ramaty et al. (1973, ▽), Smith et al. (1973, o), Badhwar et al. (1977, ▲), Seo et al. (1991, ▽), Dwyer et al. (1993, ▷), Ichimura et al. (1993, ◁), Ivanenko et al. (1993, ◓), Zatsepin et al (1993, ×), and Swordy et al. (1995, ◪).

is consistent with supernova remnant shock wave acceleration into the interstellar medium to explain the hydrogen spectrum and supernova shock wave acceleration into the stellar wind of a Wolf-Rayet star to explain the helium spectrum. The hydrogen and helium data appear to be in good agreement with the predictions of the supernova shock wave acceleration model coupled with the standard “leaky box” model describing the propagation of cosmic rays through the galaxy. The JACEE collaboration has produced the highest energy direct measurement of the cosmic ray hydrogen and helium spectra up to an energy of 800 TeV.

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University/ Industry Involvement: University of Alabama in Huntsville; University of Washington, Seattle; Louisiana State University; Institute for Nuclear Physics, Krakow, Poland; Kobe Women’s Junior College, Kobe, Japan; Kobe University, Kobe, Japan; Kochi University, Kochi, Japan; Waseda University, Tokyo, Japan; Okayama University of Science, Okayama, Japan; KEK, Tsukuba, Japan; Hiroshima University, Hiroshima, Japan; Institute for Cosmic Ray Research, Tokyo, Japan; Tezukayama University, Nara, Japan.

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